Human Research Program
Behavioral Health & Performance Element

Evidence Report Summary

Risk of Performance Errors Due to Poor Team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training and Poor Psychosocial Adaptation

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I. PRD Risk Title: Risk of Performance Errors Due to Poor Team Cohesion and Performance, Inadequate Selection/Team Composition, Inadequate Training, and Poor Psychosocial Adaptation

Description: Human performance errors may occur due to problems associated with working in the space environment, and incidents of failure of crews to cooperate and work effectively with each other or with flight controllers have been observed. Interpersonal conflict, misunderstandings, and impaired communication will affect crew performance and mission success. The history of spaceflight crews regarding team cohesion, training, and performance has not been systematically documented. Tools, training, and support methods should be provided to reduce the likelihood of this risk and improve crew performance.

II. Executive Summary

Evidence from spaceflight and ground-based studies supports the idea that both performance and health are influenced by several interpersonal and psychosocial factors related to teamwork, including team cohesion, team selection and composition, team training, and psychosocial adaptation. Spaceflight evidence regarding performance and the affect of these psychosocial factors is more limited than evidence available from ground-based research; however, numerous NASA-funded and NASA-supported reviews and reports (regarding spaceflight and space analogues) emphasize the need to consider the team and psychosocial factors affecting the team (Ball & Evans, 2001; Hackman, 1996; Helmreich, 1985; NASA, 1987; Otto, 2006; B. Paletz & Kaiser, 2007; Vinograd, 1974). There has not been a systematic attempt to measure the performance effects of team cohesion, team composition, team training, or psychosocial adaptation during spaceflight. As a result, evidence does not help us identify exactly what team composition, level of training, amount of cohesion, or quality of psychosocial adaptation are necessary to reduce the risk of performance errors in space. However, ground-based evidence demonstrates that decrements in individual and team performance are related to the psychosocial characteristics of teamwork, and there are reasons to believe that ground support personnel and crewmembers experience many of the same basic issues regarding teamwork and performance (Hackman, 1996; Lautman, 1987; Vinograd, 1974).

Although evidence does not identify specific factors or how these factors are important, evidence reviewed in this report shows that addressing the psychosocial characteristics of teamwork will promote crew health and performance. Before this knowledge can be effectively applied to long-duration missions, more research must be done to determine what practices (selection, training, coaching, psychological support, etc.) best address the psychosocial characteristics of teamwork. The BHP Element has identified the gaps in knowledge related to these issues, and a review of these gaps is provided.

III. Introduction

Evidence linking crew selection/composition, training, cohesion, or psychosocial adaptation to performance errors is uncertain, mainly due to research on performance errors itself being ambiguous. The study of performance error implies that human actions may be simplified into a dichotomy of "correct" or "incorrect" responses, where incorrect responses or errors are always undesirable. Some researchers have argued that this dichotomy is a harmful oversimplification and that it would be more productive to focus on the variability of human performance and how organizations can manage that variability (Hollnagel, Woods, & Leveson, 2006).

There are two particular problems that occur when focusing on performance errors: 1) errors are difficult to observe and record; and 2) errors do not directly correspond to performance. Research reveals that humans are fairly adept at correcting or compensating for performance errors before such errors result in recognizable or recordable failures (Hollnagel et al., 2006). Most failures are recorded only when multiple errors occur and humans are unable to recognize and correct or compensate for these errors in time to prevent a failure (Dismukes, Berman, & Loukopoulos, 2007).

More commonly, observers record variability in levels of performance. Some teams commit no observable errors, but fail to achieve performance objectives or perform only adequately. Other teams commit some errors, but still manage to perform spectacularly. Successful performance is more than the absence of errors or avoidance of failure (JSC Joint Leadership Team, 2008). NASA culture has historically hinged on the notion that 'Failure is not an option.' While failure is commonly attributed to making some fatal error, focusing solely on the elimination of error does not significantly reduce the risk of failure. Failure also occurs when performance is simply insufficient, or when an effort is incapable of adjusting sufficiently to a contextual change. The surest way to reduce the risk of failure is to achieve optimal performance. If NASA is to spend the same amount of money launching one of two crews, and both crews have equal risk of committing performance errors, but one crew is more likely to perform more of the mission objectives (or otherwise perform better), then the preferred crew remains the highest performing crew. From this point of view, the real question is how can we optimize human performance during long-duration missions?

Fortunately, the evidence linking crew selection/composition, training, cohesion, or psychosocial adaptation to performance differences are more certain and more relevant to future human space exploration operations than evidence regarding any related performance errors. The list of what we do know from existing research (ground-based, space analogue, and spaceflight) is considerable:

1. We know we can select individuals more capable of performing well in a team (Barrick, Stewart, Neubert, & Mount, 1998).
2. We know that there are different team compositions that better facilitate different types of performance (Mannix & Neale, 2005).
3. We know training individual team skills and training teams together encourages better individual and team performance (Hirschfeld, Jordan, Feild, Giles, & Armenakis, 2006; Paris, Salas, & Cannon-Bowers, 2000; E. Salas, Rhodenizer, & Bowers, 2000).
4. We know that teams that are more cohesive demonstrate better performance than less cohesive teams(Grice & Katz, 2005).

5. We know that in the event of a malfunction or error, better teamwork increases the likelihood of recovery and survival (Baker, Day, & Salas, 2006; Shapiro et al., 2004).
6. We know that members of more cohesive teams demonstrate better individual performance and report more physical and psychological resilience under duress (Kidwell, Mossholder, & Bennett, 1997; L A Palinkas, 1991; Podsakoff, MacKenzie, & Ahearne, 1997; Vallacher, Seymour, & Gunderson, 1974).
7. We know individuals and teams perform better and maintain high performance and health longer when they adapt more quickly and effectively to the stressors inherent in a psychosocial environment (Burke, Stagl, Salas, Pierce, & Kendall, 2006; Gunderson, 1966a; D.J. Lugg, 1977; Riggio, Watring, & Throckmorton, 1993).
8. We also know that psychosocial factors influencing teamwork and performance in traditional work environments appear in the space exploration work environment (Kanas et al., 2000).

Negative consequences (for example, incomplete objectives, or lost time) related to interpersonal stressors (such as isolation, confinement, danger, monotony, inappropriate workload, lack of control, group composition-related tensions, personality conflicts, and leadership issues) have been observed on previous long-duration missions (Kanas & Manzey, 2003) (Category III).

Furthermore, ground-based research indicates that interpersonal stressors are cumulative over time and pose a greater threat to performance and team success as the work duration increases (Cropanzano, 2003; Halbesleben & Bowler, 2007; Rasmussen & Jeppesen, 2006; Staal, 2004; You, Lee, & Lee, 1998) (Category II and III).

Selection, training, cohesion, and psychosocial adaptation influence performance, and as such, are relevant factors to consider as we prepare for costly long-duration missions where the performance objectives will be demanding, endurance will be tested, and success will be critical. During the selection of crewmembers, throughout training, and during the psychosocial adaptation of the crew to the mission environment, we have several opportunities to encourage optimal performance, and in turn, minimize the risk of failure. Faced with the very real prospect of needing to promote successful human explorations of the Moon and Mars within the next 15 to 20 years, research should not spend limited time and resources in attempts to quantify risks of failure or performance errors due to inadequate selection, training, cohesion, or psychosocial adaptation. Research should focus rather on how we can most efficiently optimize performance through selection, training, team building, and psychosocial adaptation. Human performance professionals currently know enough to be able to make this kind of research productive and operationally relevant within the projected time until launch. The evidence detailed in the following sections support this argument.

IV. Evidence

A. Individual Selection and Crew Composition

1. Selecting Individuals to Perform in a Team

One way of selecting for teams is to identify those individuals who are best suited to work in teams, ensuring that each individual team member at least possesses the qualities and skills that lend themselves to optimal teamwork. For example, many organizations use competency frameworks to select individuals (such as IBM, GE, Verizon, Waste Management, Hanover, Shell, 3M, the United States Office of Personnel Management) (Rodriguez, Patel, Bright, Gregory, & Gowing, 2002). Within the framework, there may be a "teamworking" competency that measures how an individual supports other team members, shares knowledge with them, and so on. There is both spaceflight (Category III) and ground-based (Category I and II) evidence to suggest that "teamwork" competencies help predict individual performance in teams.

Within spaceflight operations, several efforts have been made to identify factors that are important for selecting individual crewmembers for long-duration spaceflight (Caldwell, 2005; Galarza & Holland, 1999; Hackman, 1996; Holland, 2000; NASA, 1987; Nicholas & Fouchee, 1990; Vinograd, 1974) (Category III and IV).

Galarza and Holland (1999) conducted a preliminary job analysis to identify the skills necessary for long-duration versus short-duration missions in order to inform the initial astronaut candidate selection process (Category III).

Twenty experts (including astronaut representatives) rated 47 relevant skills on criticality and rated an additional 42 environmental and work demands on their probability of occurrence. The environmental and work demands for long-duration space missions included group dynamics within a heterogeneous crew and with external groups such as ground control. The experts' ratings resulted in 10 broad factors important for long-duration missions, including performance under stressful conditions, mental/emotional stability, judgment/decision making, teamwork skills, conscientiousness, family issues, group living skills, motivation, communication skills, and leadership capabilities. These 10 factors overlap somewhat with those identified in previous peer rating studies that suggested both a job competence dimension and an interpersonal dimension for astronaut performance (McFadden, Helmreich, Rose, & Fogg, 1994; Santy, 1994) (Category III).

In 1990, a European astronaut working group re-evaluated selection criteria for the selection of European astronauts. Although astronauts have not been historically screened for interpersonal skills, this group included social capabilities as criteria for selection (Sandal, 1999) (Category III).

Selection research within spaceflight is severely limited by the lack of job performance data available to researchers. In fairness, there is such a limited number of astronauts actually selected (around 340 U.S. astronauts over the life of the program) and so much evolution in the job duties and selection practices (from Mercury to ISS) that there are not enough consistent selection criteria or objective performance data on enough astronauts to create a reasonably sized sample for analysis. Thus, we do not have a good idea of the specific individual skills and characteristics that would best predict successful astronaut teamwork.

On a positive note, ground-based research on individual selection for work done in teams has been actively developing for over 50 years, and this research does inform astronaut selection for teamwork. In fact, ground-based studies have identified many individual teamwork-related skills and characteristics. For example, for new teams, picking individuals who are skilled at training and articulating their roles to others, skilled at compromising, skilled at helping other team members take on their tasks, and who also understand effective team processes, resulted in better performing teams than when these individual skills were ignored at selection (Jones, Stevens, & Fischer, 2000) (Category III).

Individual values also appear to make a difference, as teams with more team members who value being on a team perform better than teams with team members who do not value being on the team (Bell, 2007; E. Salas, Kosarzycki, Tannenbaum, & Carnegie, 2005) (Category II and

III). Team members who do not value being on the team are less likely to be motivated to learn team skills (Salas et al., 2005) (Category III).

Evidence suggests that individual characteristics (in addition to individual skills and values) influence performance in a teamwork setting. A recent meta-analysis found that, in lab-based team studies, team performance was significantly positively related to average team general mental ability and to average team task-relevant expertise (Bell, 2007) (Category I).

In the field studies considered, the big five personality factors (Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism) were all significantly correlated with team performance (Bell, 2007). In a traditional work environment, Barrick and colleagues (1998) found that a team member with a very low score on Conscientiousness (as measured by the NEO PI-R) had an impact on team performance by acting as the 'weakest link,' constraining team performance (Category II).

In assembly and maintenance work teams, team average on three personality factors (Emotional Stability, Conscientiousness, and Agreeableness) and general mental ability were positively correlated with supervisor ratings of team effectiveness. In addition, team average general mental ability and two personality factors (Extraversion, Emotional Stability) were positively related to supervisor ratings of the team's ability to maintain itself over time (Barrick, Stewart, Neubert, & Mount, 1998). Another review suggests that in team environments, Agreeableness and Emotional Stability are the personality characteristics most strongly associated with job performance (Stewart, 2003) (Category III).

One meta-analysis across a range of occupations found that interpersonal facilitation was significantly predicted by three personality factors (Conscientiousness, Emotional Stability, and Agreeableness) (Hurtz & Donovan, 2000) (Category II).

All of these studies provide evidence that individual factors, such as personality and general mental ability, help predict the quality of performance in a teamwork setting. Research on pilots offers further evidence that individual personality factors are relevant to selecting an individual capable of teamwork. In regards to interpersonal characteristics, a "right stuff" cluster based on the Personality Characteristics Inventory (PCI) was composed of high levels of expressivity (warmth, sensitivity), and low levels of negative instrumentality (arrogance/hostility) and verbal aggressiveness (complaining, nagging, passive-aggressive) (Chidester, Helmreich, Gregorich, & Geis, 1991; Gregorich, Helmreich, Wilhelm, & Chidester, 1989; Musson & Helmreich, 2005). A "wrong stuff" cluster included high levels of verbal aggressiveness and low level of positive expressivity; whereas, a "no stuff" included low scores on expressiveness, instrumentality, mastery, etc. The "right stuff" cluster pilots were considered more effective by observers in a one and a half day simulated trip with crew than "low stuff" and "no stuff" pilots (Chidester, Kanki, Foushee, Dickinson, & Bowles, 1990).

Navy research in Antarctica suggests that while technical competence is necessary, it is also important to select individuals who exhibit "social compatibility or likeability, emotional control, patience, tolerance of others, self-confidence without egotism, the capacity to subordinate routinely one's own interests to work harmoniously as a member of a team, a sense of humor, and the ability to be easily entertained" as well as be practical and hard working (Stuster, 1996, p. 268) (Category III).

In summary, evidence suggests that individual factors should be considered in selecting astronauts for long-duration missions, but more research within the spaceflight context must be done to determine the individual factors that are most likely to support optimal performance and minimize errors related to astronaut teamwork.

2. Composing Teams to Perform

Selecting individuals with good “teamwork” or interpersonal skills does not consider several additional factors that meaningfully impact team performance. For example, the composition of the team has a major impact on how successful a team is likely to be. Based on the Shuttle/Mir missions, Kanas and colleagues (2002) contend that composing an interpersonally compatible crew is an important countermeasure for potential psychosocial problems. While this is no doubt ideal, operational constraints have severely limited spaceflight research opportunities, and there is no empirical evidence from **spaceflight** indicating how to best compose crews that have both the right technical competencies and the right interpersonal mix to achieve optimal performance.

While the literature on individual selection for teamwork abounds, there is little research literature on composing entire teams (S. B. F. Paletz, 2006). Most ground-based studies deal with teams that are already assembled and compare team-level features associated with high or low levels of team performance. For example, teams that did not have any members particularly low in Agreeableness or Extraversion (the personality factors) were found to be high-performing teams (Allen & West, 2005) (Category II). Likewise, high performing teams had more moderate proportions of members who were more extraverted (Barry & Stewart, 1997) (Category II).

Evidence suggests team composition is a key differentiating factor between high- and low-success teams. One measure of the team composition is the heterogeneity or diversity of the team members. In one study, researchers (Harrison, Price, & Bell, 1998) have studied two types of diversity in teams and their impact on team cohesion: surface-level (i.e. gender, age, ethnicity, tenure) and deep-level (attitudes, values, beliefs, cultural norms) diversity. Surface-level diversity includes heterogeneity in age, sex, race, and to a lesser extent, how long the individual has been a part of the organization (i.e. tenure). Heterogeneity at a deep level includes differences among members’ attitudes, values, beliefs, and cultural norms. Information about deep-level factors is communicated through verbal and nonverbal behavior patterns and is only learned through extended, individualized interaction (Harrison et al., 1998). Attitudinal similarity may facilitate communication and may also reduce role conflict as communication on the job increases and team members realize they share similar conceptualizations of their organizations and jobs (Tsui, Egan, & O'Reilly, 1992). Although we do not know to what extent future exploration missions will be based on international partnerships, it is important to remember the deep-level diversity associated with differing cultural norms.

Several studies have reported that deep-level similarity is one of the most important predictors of team cohesion (Byrne, 1971; McGrath, 1984) and long-term performance (Edwards, Day, Arthur, & Bell, 2006; Hirschfeld et al., 2006). In contrast, studies generally do not find support that surface-level diversity affects long-term performance; rather surface-level diversity affects short-term performance until team members have enough time to get to know each other and the focus shifts away from surface-level differences. For example, Schmidt, Wood and Lugg (2004) found that perceptions of leadership effectiveness were significantly related to the team’s general satisfaction with their work, performance, and each other, but they did not find any evidence that diversity in demographic composition variables (age, gender, tenure) was related to the team’s satisfaction (Category III).

While some studies indicate that surface-level diversity affects performance and decision making, these studies focus on short-term performance and decisions that require greater creativity (for example, advertising decisions) (Bell, 2007; D. A. Harrison, Mohammed, McGrath, Florey, & Vanderstoep, 2003). Surface-level diversity effects dissipate over time and are not likely to enhance teams' ability to avoid "group think" or continue creative problem solving; whereas, deep-level diversity effects have little impact on short-term performance but become more salient the longer teams exist (Harrison et al., 1998).

In regards to identifying the right "mix" of team members, research indicates that different kinds of diversity have different consequences on team conflict, and in turn, on team performance (Lisa Hope Pelled & Xin, 2000). An important distinction in the team conflict literature is that between interpersonal conflict and task conflict (De Dreu & Weingart, 2003). Interpersonal conflict is generally found to be destructive of team performance, while task conflict in moderate amounts is generally found to promote task performance because team members may correct each other's misperceptions or argue out better alternatives (L. H. Pelled, Eisenhardt, & Xin, 1999; Porter & Lilly, 1996).

In a review of the literature, Mannix and Neale (2005) concluded that surface-level differences (such as demographics) have a negative impact on the short-term performance of teams as these teams initially experience more interpersonal conflict, but these differences have less impact on performance the longer teams are together. Deep-level diversity has a negative impact on long-term performance only when teams are not provided with the training and incentives to manage interpersonal conflicts. When training and incentives for managing diversity are provided, then deep-level diversity helps teams maintain moderate amounts of the positive task conflict that supports team performance. Mannix and Neale (2005) suggest that giving teams ample time to train together and instructions on how to take advantage of multiple perspectives reduces the odds of interpersonal conflict stemming from either surface- or deep-level diversity and increases teams' ability to leverage the task conflict (Category III). If future exploration missions involve international partnerships, it may be difficult to schedule crewmembers enough time to train together and learn to leverage their differing cultural norms.

In summary, the relationship between deep-level diversity, conflict, and team performance is of more interest for long-duration missions than surface-level diversity. Research must help determine what deep-level diversity actually exists among crews, what deep-level characteristics impact astronaut performance, and what kinds of operational interventions (such as composition considering interpersonal compatibility, time training together, etc.) will promote optimal performance.

B. Team Skills Training for the Individual and for the Collective Team

Long-duration spaceflights, such as International Space Station (ISS) missions, are so physically, mentally, and emotionally demanding that simply selecting the individual crewmembers with the "right stuff" is not sufficient. Training and supporting optimal performance, as well as selecting high performers, is a more effective and efficient approach than just selecting the high performers (Holland, Hysong, & Galarza, 2007). Training and supporting optimal performance involves more than educating astronauts about the technical aspects of the job – it also requires equipping astronauts with the resources to maintain their psychological and physical health in an isolated, confined, and extreme environment over an extended period of time.

Developing the right kind of training to support astronaut performance is complicated by several operational issues. For one, getting an accurate picture of what knowledge and skills are required for successful performance is difficult. Not all tasks or even types of tasks can be anticipated. On an exploration mission new tasks may arise suddenly, and training needs to be broad and flexible enough to support unexpected performance requirements. For another, space exploration is a relatively new job, and not a lot of people have performed it, particularly for the long-duration missions (only four humans have lived and worked in space for one year). While all experienced astronauts are polled for this information on a regular basis, there are a limited number of experienced astronauts to help describe what kind of training they found useful on the job and what kind of training has not been critical to their performance. This situation makes reliably describing successful performance more difficult and evaluating the relationship between training and performance improvement more challenging.

Also, astronauts are required to both live and work together. Performance expectations include maintaining a healthy psychological and social environment in addition to achieving technical objectives. Astronaut performance is also largely team-dependent. While some tasks are done independently, subject matter experts within the space agencies argue that teamwork skills are important to accomplishing overall mission objectives safely.

The Human Behavior and Performance Training Working Group[1] recently articulated training requirements necessary to promote ISS astronaut performance, and teamwork was one of the eight primary categories of training requirements. The group recommended that crewmembers complete at least one technical training event as a team (Human Behavior and Performance Training Working Group, 2007). Additionally, NASA's Mission Operations Directorate trains teamwork as one of nine primary spaceflight resource management skills sets for flight controllers, flight directors, and flight crews during mission operations (Mission Operations Directorate, 2007).

Furthermore, astronauts perform complex technical tasks at the forefront of modern science and human limitations. Astronauts currently complete a rigorous technical training curriculum, which can span two to five years. Adding requirements to practice or perfect skills is a critical concern for schedulers. If, as research suggests, teaching team members to exchange mental models and perceptions about performance can reduce the amount of time required to master a skill (Cannon-Bowers & Salas, 1998a; Edwards et al., 2006) (Category II), then training team skills results in technical training efficiencies. Accordingly, a meta-analysis conducted by Guzzo, Jette, and Katzell (1985) of 97 studies, involving 11 different types of interventions, found training and goal-setting to be the most effective organizational interventions aimed at increasing motivation and individual performance (Category II).

These findings support the idea that training is one of the best interventions for addressing the psychosocial characteristics of teamwork, and as such, training offers NASA a great chance to promote crew health and optimal performance on long-duration missions. Evidence indicates that two specific facets of training are relevant to team performance: 1) individual training on teamwork and interpersonal skills, and 2) time training as a team.

1. Teamwork and Interpersonal Skills for the Individual

Spaceflight evidence regarding teamwork and interpersonal skills training is more limited than ground-based evidence. Prior to starting space station operations, NASA provided a discussion and resource guide for Astronauts preparing for station that defined effective teamwork and highlighted several individual strategies for ensuring team performance (Galarza et al., 1999), thus implying that training teamwork skills was at least operationally relevant to long-duration missions.

Many training efforts in industry and in the military focus on developing the interpersonal skills of group members to enhance team performance. Arthur and colleagues (2003) classified studies in terms of three learning objectives: cognitive, interpersonal, and psychomotor skills. Four different training criteria were identified: reaction (self-report), learning (test performance, usually pencil and paper), behavior (on-the-job performance, supervisor ratings or objective measures), and results (company-Category productivity, profits or return-on-investment). Arthur and colleagues (2003) concluded that cognitive and interpersonal skills training had the largest positive effects on the behavioral criteria, indicating that interpersonal skills training specifically benefits job performance (Category II).

Bradley and colleagues (2003) concluded that interpersonal skills training also contributed to good supervisor ratings of team performance in ongoing teams for both short- and long-duration tasks, and also for short-term teams engaged in long-duration tasks (Category II).

The interpersonal skills that contributed to performance included role clarification, goal setting, identifying work priorities, group problem solving, team coordination, interpersonal relations and understanding, consensus building and conflict management. Dependent measures that showed improvements included cohesion, personal growth, motivation, team performance, work efficiency, and job satisfaction.

Baker and colleagues (Baker et al., 2006) investigated the impact to training teamwork skills on surgical team performance and errors and noted that the training significantly improved patient mortality rates and reduced the amount of surgical errors (Category II).

Powell and Hill (Powell & Hill, 2006) noted reductions in adverse patient outcomes, medical errors, nursing attrition, and conflicts after implementing crew resource management (a form of teamwork and psychosocial skills training) in health care arenas (Category III).

In a review of factors that determine a team's ability to adapt their performance to successfully handle changing conditions, Burke and colleagues (Burke et al., 2006) found that training teamwork skills and cross-training team members resulted in the most adaptive teams (Category III).

In a laboratory simulation, Marks and colleagues (Marks, Zaccaro, & Mathieu, 2000) found that training designed to improve individuals' communication and interaction skills improved team performance under novel work conditions (Category I). In a similar study done with 60 graduate students in assigned teams, Smith-Jentsch and colleagues (Smith-Jentsch, Salas, & Baker, 1996) found that training students how to be appropriately assertive and speak up about team performance issues significantly improved a teams' ability to adjust their performance.

Leedom and Simon (Leedom & Simon, 1995) found that providing Air Force aviators with standardized, behavior-based training on teamwork increased team coordination and improved team task performance.

Other studies suggest that teams composed of team members with more knowledge about teamwork perform better than teams composed of team members with less knowledge about teamwork (Morgeson et al. 2005; (Hirschfeld et al., 2006). In a manufacturing organization, Morgeson and colleagues (2005) observed that individual knowledge about teamwork helped to predict team performance. In a field study of 92 teams (1,158 team members) in a United States Air Force officer development program, Hirschfield and colleagues (2006) found that team members' mastery of teamwork knowledge predicted better team task proficiency and higher observer ratings of effective teamwork.

The bottom line is that teamwork and interpersonal skills training promotes team performance. Research must still help determine the best kinds of interpersonal and teamwork skills training and the best implementation means for supporting optimal team (that is, the whole mission team, including flight crew and ground control) performance during long-duration missions. Evidence suggests that training teams as a team also contributes to team performance (see below).

2. Training Team Skills to the Collective Team

Spaceflight evidence regarding the effectiveness of team training in promoting team performance consists largely of professional opinion and anecdotal stories advocating the importance of team building for astronauts and ground support (Category III and IV). Nicholas (1989) argued that some problems encountered by crews can only be settled by training the crew as a whole in interpersonal, emotional-support, and group- interaction skills (Category IV).

The Panel of Human Behavior’s (Panel on Human Behavior, 1998) report on “Behavioral Issues” advised that crews and ground support personnel be trained together on interactive techniques prior to flight (Category IV). Over the last three years, several Space Shuttle crews have opted to complete expedition interpersonal training as a team in order to enhance their “cohesion and performance” (in personal communication, Shultz, 2007) (Category III).

Ground-based research supports the idea that employees interacting in stressful environments, with high workloads, or in environments requiring coordination at a distance (similar to ground support and flight crews operating together) need team training (D. A. Harrison et al., 2003; Ilgen, Hollenbeck, Johnson, & Jundt, 2005) (Category III).

In a study of 27 manufacturing teams (263 individuals) who had worked together an average of 1.9 years, Austin (Austin, 2003) found that team performance depended on how well the individual team members could describe what knowledge resources the team possessed and how those knowledge resources could be applied to new situations. This finding supports the notion that giving team members the opportunity to learn about each other’s task-related knowledge and skills supports team performance. Research indicates that more experience working together bolsters teams’ performance in a variety of ways, and team training is one means of ensuring team members gain some experience working together (Paris et al., 2000). For example, in a study of submarine attack crews, Espevik and colleagues (Espevik, Johnsen, Eid, & Thayer, 2006) found that knowledge about team members added to the number of hits on target, over and above the contribution from operational skills (Category II).

In addition, the authors found that the more experience crews had working together, the less physiological arousal the crew experienced during the attack simulations. In a study comparing 83 work dyads, Edwards and colleagues (Edwards et al., 2006) found that more time spent working and training with their team members made junior and minority team members more likely to contribute, and that teams where individuals contributed more information performed better than teams where one individual provided larger portions of information (Category III).

More conflicts are generally associated with more stress, increases in errors, and decreases in productivity (Alper, Tjosvold, & Law, 2000). In a review of 55 studies, Rasmussen and Jeppesen (2006) noted that every study found that the more time teams spent training together, the fewer conflicts and conflict-related performance deficiencies teams experienced (Category III).

In a review of applied findings from team performance training done in military settings, Cannon-Bowers and Salas (1998b) concluded that it was important for teams to practice complex or off-nominal situations together (Category III). Also, in a review of simulation-based training practices, Sallas and colleagues (2007) observed more benefits to team performance from letting teams practice complex and emergency simulations together than they did from training team members in the simulations in random groups.

A meta-analysis of 37 work teams found that teams with densely configured interpersonal ties are more committed to staying together and attain more performance goals (Balkundi & Harrison, 2006). The authors noted that team training is one mechanism for increasing team familiarity and the density of interpersonal ties; however, it is important to note that non-work oriented team training may not be sufficient, nor worthwhile by itself. Studies with geographically distributed teams that compare task-based team training with more socially-oriented time together, indicate that teams that are familiar socially, but have little to no experience working together as a team, do not realize the same performance benefits as teams with experience working together (Espinosa, Slaughter, Kraut, & Herbsleb, 2007; Kirkman, Rosen, Tesluk, & Gibson, 2006) (Category II).

In so far as team training requires team members to complete a task or objective as a team, team training encourages better team performance. Interpersonal skills training intended to improve team member interactions, and other teamwork skills training also encourages better individual and team performance. The evidence indicates that training may be designed to promote flight crew and ground support team health and optimal performance, yet research is necessary to determine the most appropriate designs for preparing for long-duration missions.

C. Cohesion

Festinger (1950) originally defined group cohesiveness as the strength of members' motivations to stay in the group and cited three primary characteristics: interpersonal attraction, task commitment, and group pride. As research accumulated, many attempts have been made to operationalize and measure cohesion. To determine the strength or willingness of individuals to stick together and act as a unit, studies have most consistently assessed the level of conflict, the degree of interpersonal tensions, the facility and quality of communications, a group's collective perceptions of team health and performance, and the extent to which team members share perceptions or understandings about their operational contexts.

As the United States Army Research Institute (ARI) notes in a recent review of cohesion as a construct, the definition of cohesion is ambiguous, and thus the means of measuring cohesion is complex. The ARI concluded, "cohesion can best be conceptualized as a multidimensional construct consisting of numerous factors representing interpersonal and task dynamics" (Grice & Katz, 2005). Despite the inexact, less than rigorous understanding of cohesion as a construct, ARI does note that anyone who has worked or played on a team knows what a cohesive team looks like and believes that teams that are more cohesive usually perform better than less cohesive teams.

Additionally, research does tell us what cohesive teams look like. Members of cohesive teams sit closer together, focus more attention on one another, show signs of mutual affection, and display coordinated patterns of behavior. Members of cohesive teams who have a close relationship are more likely to give due credit to their partners. In contrast, those who do not have a close relationship are more likely to take credit for successes and blame others for failure (Thompson, 2002).

Psychosocial experts within the spaceflight research community have articulated the concern that interpersonal conflicts and lack of cohesion will impede crews' abilities to perform their tasks accurately, efficiently, or in a coordinated manner during long-duration missions (Hackman, 1996; NASA, 1987; Vinograd, 1974) (Category IV).

Spaceflight evidence regarding cohesion and performance is limited by the paucity of objective team performance data. However, case studies, interviews, and surveys done within the space-flight realm provide evidence that issues pertaining to cohesion exist and are perceived as threats to effective operations. For example, breakdowns in team coordination, resource and informational exchanges, and role conflicts (that is, common indicators of poor cohesion) were mentioned as contributors to both the Challenger and Columbia shuttle accidents (*Columbia Accident Investigation Board Report*, 2003; Launius, 2004) (Category IV). Likewise, interviews and surveys conducted with flight controllers revealed that mission teams are commonly concerned with team member coordination and communications, and that interpersonal conflicts and tensions exist (Caldwell, 2005; Parke, Orasanu, Castle, & Hanley, 2005) (Category III).

The bulk of evidence (Category I, II, and III) surrounding cohesion and performance comes from non-space domains such as aviation, medicine, the military, and space-analogues. In aviation, various reports have estimated that "crew error" contributes to 65 to 70 percent of all serious accidents (Lautman, 1987; Sumwalt & Watson, 2001) (Category III).

Accident investigations and mishap reports note poor teamwork, communication, coordination, and tactical decision making as significant causal factors in mishap samples (NTSB, 1994) (Category III). Team breakdowns are repeatedly implicated in accidents (Merket & Bergondy, 2000; Nagel, 1988) (Category III).

In medicine, research indicates that interpersonal conflicts, miscommunications, failures to communicate, and poor teamwork skills contribute significantly to the rate of medical errors (Baker et al., 2006; McKeon, Oswaks, & Cunningham, 2006; Powell & Hill, 2006) (Category III).

Four meta-analyses (Category I) conducted across industries and types of performance teams (work, military, sport, educational, project, etc.) provide further ground-based evidence that cohesion is related to performance. The first meta-analysis conducted by Evans and Dion (1991) found a positive correlation between cohesion and individual performance, but the study did not include group performance criterion measures. Mullen and Copper (1994) addressed these limitations in a subsequent meta-analysis and found cohesion positively effected performance. They also found that this relationship was stronger in real (vs. ad hoc) teams, in small (vs. large) teams, and in field studies. Mullen and Copper (1994) noted that successful performance also promoted cohesion. Oliver and her colleagues (2000) analyzed 40 years of military research, and noted positive relationships between cohesion and numerous performance outcomes, including individual and group performance, behavioral health, job satisfaction, readiness to perform, and absence of discipline problems.

In the latest meta-analysis, Beal et al. (2003) re-analyzed the studies included in Mullen and Copper plus additional studies. Beal and colleagues (2003) found that as the work required more collaboration, the cohesion-performance relationship became stronger, and highly cohesive teams became more likely to perform better than less cohesive teams. This conclusion coincides with Thompson's (2002) cumulated field study finding that cohesion facilitated team processes and team coordination among work teams in various industrial settings (Category III).

In a meta-analysis of 67 ground-based experimental studies, Gully and colleagues (2002) (Category I) noted a significant positive relationship between performance and teams' generalized beliefs about the capabilities of their team across different situations. While most of the research on team cohesion and performance deals with the positive aspects of team attitudes, several studies investigated level of conflict and negative attitudes about the team as indicators of cohesion. An important distinction is that between interpersonal conflict and task conflict (De Dreu & Weingart, 2003). Interpersonal conflicts are about relationship issues; whereas, task conflicts are about how to handle tasks.

Interpersonal conflict is generally found to be destructive to cohesion and, in turn, team performance; whereas, task conflict can improve task performance. Team members may correct each other's misperceptions, offer alternatives, and argue about how to solve a problem (Jehn & Mennix, 2001) (Category III). Thus, interpersonal conflict is generally detrimental, as it appears to affect team cohesion. Some level of task-related conflict may be desirable, regardless of its affect on cohesion, to promote optimal performance. In contrast, both interpersonal and task-related cohesion are generally found to influence performance positively. In a study conducted with Canadian military groups, path analysis showed that task-related cohesion was positively related to individual job satisfaction, interpersonal cohesion was negatively related to reports of psychological distress, and both types of cohesion were positively related to job performance (Ahronson & Cameron, 2007).

Research conducted within Antarctic space-analogues investigated conflict, cohesion, and performance as well. In one survey of expeditionary crews, conflict, measured as intermember hostility, was related to supervisor poor ratings of member effectiveness (Vallacher, Seymour, & Gunderson, 1974). In one expedition, scientists reported that team members' perceptions of status contributed to conflicts and reduced perceptions of cohesion (Dutta Roy & Deb, 1999) (Category III).

Additionally, Wood and her colleagues (2005) collected data on human performance in Antarctica over a ten-year period, modeling individual and group effects on adaptation to life in this extreme environment using multilevel analyses (Wood et al., 2005) (Category III). Positive team climate and cohesion helped to reduce interpersonal tensions, which in turn, contributed to work satisfaction (Wood et al., 2005).

Cohesion studies conducted by the military and in aviation industries have focused more on task cohesion and the role of shared mental models. Shared mental models (SMMs) refer to implicit agreements in team member's expectations about how things work and what behaviors will result in various conditions. SMMs are proposed to characterize cohesive work teams (Baker et al., 2006; Edwards et al., 2006; Hirschfeld et al., 2006). Studies comparing performance during simulated operations and training note members of high-performing teams coordinate with one another frequently to establish, maintain, and adapt SMMs as the situation evolves (Edwards et al., 2006; Espevik et al., 2006; Wech, 2002) (Category II).

Teams with little to no training on developing or coordinating SMMs demonstrate more errors and are less productive compared to teams that have received training on building SMMs (Edwards et al., 2006; Espevik et al., 2006; Hirschfeld et al., 2006) (Categories II and III).

Studies manipulating stressors facing flight simulation crews have found that cohesive teams enhance their performance under stress by shifting from using more time-consuming explicit coordination strategies to using more streamlined implicit coordination strategies to share mental models and information (Bowers et al., 2002; Driskell, Salas, & Johnston, 1999; Entin & Serfaty, 1999; D. Serfaty, Entin, & Johnston, 1998) (Categories I and II).

Effective teams shared more task-critical information than less effective teams, especially concerning the problem at hand, task goals, and team strategies (Bowers, Jentsch, Salas, & Braun, 1998; Helmreich & Sexton, 2004; L. & Sexton, 2004; Orasanu & Fischer, 1992) (Categories II and III). Moreover, members of effective teams tended to anticipate each other's needs and to volunteer information and assistance more frequently (Orasanu & Fischer, 1992; Daniel Serfaty, Entin, & Volpe, 1993) (Category III).

In summary, spaceflight evidence indicates that cohesion is a relevant concern for long-duration missions. For example, the delays in communicating with ground team members inherent in long-duration flight are likely to impact two key factors of team cohesiveness: the quality of communication; and the quality of leader support.

There is a large body of ground-based evidence showing cohesion influences levels of performance, but this evidence is primarily correlational rather than causal. Cohesive teams are more productive than are less cohesive teams and this situation could be because 1) more productive teams become more cohesive, or 2) more cohesive teams become more productive. Teams preserve their cohesion when they succeed rather than fail. Therefore, applied scientists advise it is important to promote three essential conditions for team performance: ability (knowledge and skills); motivation; and coordination strategy. Team members need to have sufficient levels of interpersonal and technical skills to perform their jobs and to attain team objectives. Team members must also be motivated to use their knowledge and skills to achieve shared goals. Team context (organizational context, team design, and team culture) must create conditions to avoid problems such as social loafing, free riding, or diffusion of responsibility. These kinds of problems undermine team performance and have detrimental effects on team cohesion (Thompson, 2002).

From the evidence, we cannot say that ignoring team cohesion is statistically likely to result in numerous performance errors or an observable failure, but we can say that ignoring the relationship between cohesion and performance is likely to result in sub-optimal performance (Grice & Katz, 2005). We know that many factors contribute to how cohesion is built and encouraged within a team, and we know that cohesion is positively related to better performance. Research cannot effectively determine in a reasonable amount of time what minimum level of cohesion is required to avoid catastrophic failure, and such an effort is probably not worth public funds compared to other research endeavors. A better research endeavor is an empirical effort to test and identify effective means of building cohesion and promoting optimal performance in a long-duration mission context. This kind of research would generate enough immediate intellectual and operational benefits to justify funding.

D. Psychosocial Adaptation

Long-duration spaceflight is a unique environment with unique conditions. On one hand, research suggests long-duration spaceflight may offer salutogenic conditions (Lawrence A. Palinkas, 2003) (Category III). Spaceflight offers the thrill of doing what few people have done before and the challenges of discovery, and these conditions foster the personal growth of individuals (Suedfeld & Steel, 2000) (Category III). On the other hand, stressful conditions are also inherent to long-duration missions. In the sense that working in space involves danger, isolation, and confinement, space is understood as an extreme work environment.

Survival in space requires constant shelter or protective gear, and survival is also subject to equipment malfunctions. These survival requirements present a certain level of danger or threat that crewmembers must adapt to. Crewmembers must also adapt to certain levels of isolation as contact with others (outside of the immediate crew) may be very limited and inconsistent at times. Finally, crewmembers must adapt to confinement to a limited living and working space.

Ground-based research involving similar conditions (submarines, offshore oil rigs, polar stations, etc.) has found such conditions to be generally detrimental to psychological health and social well-being over prolonged periods (Braun & Sells, 1962; Britt & Bliese, 2003; Krueger, 2001; NASA, 1987). The exact mechanics are not well understood, but ground-based evidence suggests social isolation is thought to be particularly detrimental to individuals' health. Epidemiologists have noted higher mortality rates among socially isolated patients (House, 2001) (Category III); and physicians have described more issues with depression and somatic illnesses in conjunction with longer periods of relative social isolation among Antarctic expeditioners (D.J. Lugg, 1977; Desmond J. Lugg, 2005; Otto, 2006) (Category III).

Suedfeld and Steele (Suedfeld & Steel, 2000) concluded that the objective characteristics of an extreme environment are less important than the subjective perceptions of the environment in relation to performance. In general, individuals who perceive they are well adjusted perceive fewer physical pains and less mental anguish, and in turn learn more and are more productive than individual who perceive they are not well adjusted (Joshi, Bhargava, & Sachdeva, 1998; LePine, LePine, & Jackson, 2004; Mocellin, 1995; Staal, 2004; Williams, Gavin, & Williams, 1996) (Category III). Likewise, individuals who have socially adapted enough to form interpersonal networks at work have more access to critical information and resources, and in turn are able to accomplish more than less socially adapted individuals with smaller interpersonal networks (Balkundi & Harrison, 2006; Burke et al., 2006; Johnson, Boster, & Palinkas, 2003; Schaninger, 2002).

The psychological and social adjustment of an individual to environmental conditions is known as psychosocial adaptation. The bottom line is psychosocial adaptation influences individual health, learning, productivity, and performance.

Successful completion of technical objectives is not enough to consider a long-duration mission successful. The crew must also return home safely with psychological health intact, thus we are concerned with helping individuals adapt quickly and effectively to long-duration spaceflight. Observations indicate 1) individual factors help predict who is more likely to adapt effectively to the psychosocial requirements of long-duration missions (Gunderson & Nelson, 1963a; Kanas & Manzey, 2003; D.J. Lugg, 1977) (Category III) and 2) contextual factors help predict how well individuals may be able to adapt (Boyd, 2001; D.J. Lugg, 1977; Lawrence A. Palinkas, 2003; L A Palinkas, 1991) (Category III).

Focusing on individual and contextual factors that predict psychosocial adaptation will allow research to build the support and countermeasures necessary to encourage optimal performance and ensure mission success.

1. Predicting Individual Ability to Adapt

A significant challenge of collecting data in flight is that the data are from a small or limited number of subjects, and many measures of psychosocial adaptation require a comparatively large amount of subjects' time (such as extensive questionnaires on a repeated basis, repeated collection and storage of physiological stress data, etc.). Thus, the bulk of evidence available regarding adaptation to long-duration missions comes from space-analogues, mainly from Antarctic expeditions. Findings from Antarctic studies note adapting is an individual process. Not all individuals successfully adapt to the psychosocial conditions of an isolated, confined, and extreme environment; for these individuals, performance and health usually suffer. In an early correlational study comparing expeditionary groups, Gunderson and Nelson (1963b) found a group rated as less effective also reported being more bored, less compatible, less motivated, and less socially balanced than a higher performing group (Category III). To the extent these perceptions can be viewed as indicators of adaptation, a better-adapted group appears to be a more effective group.

Regarding individual performance, Palinkas (1987) found no significant differences between group members who wintered-over and those of a control group in terms of long-term performance (Category II). Wintering over itself, then (versus completing long-duration expedition without winter) does not appear to have a lasting effect on performance; however, adapting to one's work requirements on Antarctica was associated with an exaggeration of perceived injustices (D.J. Lugg, 1974) (Category III), and, failure to perform well appears to affect continued adaptation. One low performer became a social isolate as the result of his poor performance (D.J. Lugg, 1974)—suggesting the adaptation-performance relationship is reciprocal for at least some individuals (Category III).

Crocq and colleagues (1974) found age was not correlated with adaptation among Antarctic expeditioners. Although some anecdotal evidence suggests the youngest personnel sometimes have more difficulty adapting than do their elders. Previous medical history and cognitive ability also predicted adaptation among Antarctic expeditioners (D.J. Lugg, 1974). Crocq and colleagues (1974) found high cognitive ability had a positive relationship with adjustment. Low cognitive ability, however, did not necessarily indicate a corresponding poor ability to adapt. Various personality characteristics of the individual Antarctic station members and attitudes they hold were found to predict adaptation. Individuals low in extroversion and assertiveness adapt better to life in Antarctica (Rosnet, Le Scanff, & Sagal, 2000). However, as noted previously, ground-based evidence indicates teams with more moderately extroverted individuals generally perform better (Allen & West, 2005; Barry & Stewart, 1997).

Research must still determine how to balance individual's extroversion at levels encouraging to both psychosocial adaptation and team performance. In fact, many characteristics influence adaptation and several are likely to call for balancing within teams performing in extreme environments. As Gunderson (Gunderson, 1966b) noted "achievement needs, needs for activity, needs for social relationships and affection, aesthetic needs, needs for dominance or leadership, a sense of usefulness in one's job, and control of aggressive impulses to be particularly important for adjustment in small Antarctic groups" (p. 4).

Generalizing the results found in Antarctica to spaceflight require caution. For one, any generalizations of Antarctic findings to space require the differences between the two environments to be taken into account. Group size, for example, is larger in Antarctica than on spaceflights. Given group size has been seen to affect aspects of life in Antarctica, the degree to which Antarctic findings involving groups can be generalized to space might be limited. And two, any conclusions made regarding factors affecting performance in Antarctica are based on relatively few articles.

Ground-studies conducted in traditional work environments regarding psychosocial adaptation and performance offer a broader base of evidence and some insight into the general principles of psychosocial adaptation to work; however, the utility of these findings are limited by the critical fact that most employees do not live exactly where they work, as long-duration mission participants must. Ground-based studies support the conclusion that some individual factors predict ability to adapt. Caldwell and colleagues (2005) found a small group of pilots and a control group of non-pilots who exhibited more cortical activity were less vulnerable to cognitive performance decrements and emotional distress related to 36-hour sleep decrements. Additionally, LePine and colleagues (2004) found selecting adult learners with positive affect for a complex training program reduced resulting reports of fatigue and exhaustion (Category II).

Independent of any particular stressor or stressful environments, Greenberg and colleagues (1992) observed individuals with more self-esteem generally experience less anxiety under the same or similar conditions as individuals with less self-esteem (Category II).

The existing evidence is a starting point, but more research is needed. Achieving a better understanding of the individual factors influencing astronaut's ability to adapt to long-duration space missions would generate at least two operational benefits: 1) individual factors that predict adaptability could be used to aid selection or assignment decisions, and 2) these individual factors could be used to customize psychosocial support and resources to fit individual crewmembers.

2. Contextual Factors Influencing Adaptation

Factors outside of the individual (duration of stressful conditions, coping resources available, etc.) can also help predict adaptation. For example, a slow voyage to Antarctica and living and working in a larger station once in Antarctica, predicted adjustment (D.J. Lugg, 1974) (Category III). Composition of the group and job skills of group members also predicted adapting to the new environment (D.J. Lugg, 1974). Many such contextual factors influence adaptation by contributing to individuals' stress perceptions. Stress is the disruption of homeostasis through physical or psychological stimuli known as stressors. According to the Mirriam-Webster Dictionary ("Merriam-Webster's Collegiate® Dictionary," 2007), stress is defined as, "a physical, chemical, or emotional factor that causes bodily or mental tension and may be a factor in disease causation." Some stress is unavoidable, like the stress of competition during a game, and some stress is good as the inverted-U of the performance-anxiety relationship demonstrates (Abramis, 1994). However, some stressors are so acute even small amounts cause serious performance decrements (Abramis, 1994) (Category II), and chronic (long-term) stress or many acute stressors lead to strain or burnout (Barnett, Baker, Elman, & Schoener, 2007; Freedy & Hobfoll, 1994; Hobfoll, Shirom, & Golembiewski, 2001; van Gelderen, Heuven, van Veldhoven, Zeelenberg, & Croon, 2007) (Category II and III).

For example, Adler and Dolan (2006) found the longer peacekeeping mission deployments for 3,339 military personnel were associated with increased reports of depression and post-traumatic stress syndrome (Category III). This indicates there may be a limit to how long an individual can adapt to a particular environment or related stressors. From a spaceflight perspective, MIR operations indicate astronauts and cosmonauts are capable of adapting to 6 months in orbit, but reports indicate many MIR participants on longer duration flight (over 6 months) developed symptoms of fatigue, irritability, and minor disorders of attention and memory (Boyd, 2001; Kanas et al., 2001) (Category III).

There are individual differences in perceptions of and adaptations to particular stressors, and there are many different potential stressors inherent in a long-duration mission. Two typical stressors (isolation and confinement) have already been discussed. More research is needed; particularly research involving ISS astronauts, to determine what other stressors might impact astronauts' psychosocial adaptation on future missions. Research is also needed to determine what coping mechanisms and contextual factors best support psychosocial adaptation within the operational constraints of long-duration spaceflight.

Ground-based evidence indicates social support is a contextual factor in traditional work environments that improves adaptation and resilience to various stressors. Social support has traditionally been operationalized as any assistance individuals receive from others through interpersonal interactions, including information, emotional care, or instrumental resources (Buunk, Doosje, Liesbeth, & Hopstaken, 1993; Riggio et al., 1993).

Ground-based research indicates social support helps individuals cope with psychosocial stressors (Anderson, 2003; Riggio et al., 1993; Seers, McGee, Serey, & Graen, 1983) (Category II). Individuals who received less social support were more likely to commit suicide, have accidents, incur injuries, or develop illnesses over their lifespan than individuals who had more social support available to them (Buunk, Doosje, Jans, & Hopstaken, 1993; House, Landis, Umberson, Salovey, & Rothman, 2003; Israel, House, Schurman, & Heaney, 1989; LaRocco, House, & French, 1980; Nowack, 1991) (Category II and III).

Additionally, ground-based research indicates that social support plays a positive role in team functioning, team performance, individual achievement, and employee safety (Bhanthumnavin, 2003; Buunk, Doosje, Jans et al., 1993; Buunk, Doosje, Liesbeth et al., 1993; Heaney, House, Israel, & Mero, 1995; Hearns & Deeny, 2007; Nowack, 1991; Schaubroeck & Fink, 1998; Seers et al., 1983; Settoon & Mossholder, 2002) (Category II, III, and IV). Thus, there is ample reason to consider social support as an important contextual factor promoting psychosocial adaptation. No doubt, the ground crew along with the family and friends of the flight crew will serve as a social support system to the flight crew; but communication lags on longer duration missions may stress social support system more than previous experiences in space would lead us to expect. Flight operations would benefit from pre-identifying practical ways to provide and sustain social support systems in a long-duration mission context.

Based on the literature, long-duration missions in extreme environments (Antarctica or space) require mission participants to adapt or cope with several inherent emotional stressors (such as isolation from family and friends, limited communication opportunities, limited stimulation, etc.) (Kanas & Manzey, 2003; Mocellin & Suedfeld, 1991; Natani & Shurley, 1974; Nelson, 1962; Otto, 2006 ; L A Palinkas, 1991; Vinograd, 1974) (Categories III and IV). The evidence indicates 1) optimal performance depends on coping with these stressors, 2) there is a lot of individual variance in how and how well people cope, and 3) many factors influence how well individuals are able to cope and adapt. The critical point for long-duration spaceflight is to determine the viability and utility of these factors for supporting the crews' psychosocial adaptation to training, flight, and recovery – by doing so, research will reduce the negative health impacts related to perceived stress and help optimize performance on long-duration missions.

V. Computer-based Simulation Information

This section is not applicable to this risk.

VI. Risk in Context of Exploration Mission Operational Scenarios

Given that we know selection/composition, training, cohesion, and psychosocial adaptation influence performance, many operationally-relevant questions remain for research to address, including: What mix of crewmembers are likely to perform best?, What kind of team skills training and team training is most useful for teams living and working together on a long-duration mission?, and What kinds of resources and support will facilitate psychosocial adaptation to a long-duration environment when outside intervention and facilitation is severely limited by communication lags?

As previously detailed in this document, ground-based evidence demonstrates poor selection, ineffective team composition, inadequate training, and poor psychosocial adaptation limit performance. A possible qualitative likelihood scale for performance errors during certain mission operational scenarios is:

- Level 1- will most likely not occur
- Level 2- could occur
- Level 3- will most likely occur

Using this scale, the likelihood of performance errors due to some combination of these factors onboard ISS is considered by BHP as a risk that could occur, especially during mission of six months or over with a crew of six. Similarly, this is a Category 2 risk for lunar short-duration. For the lunar long-duration and Mars missions this is a Category 3 risk, as longer duration increase the likelihood of conflict, fatigue and many other contributing factors.

While crewmembers often engage in expeditionary training activities (such as NOLS) to promote team cohesion, there is no scientific evidence regarding what type and method of training offers the best means of promoting team performance for long-duration missions. As the number of crewmembers involved in long-duration missions increases (from three ISS crewmembers to potentially seven Mars mission crewmembers), the complexity of crew communications and likelihood of inter-crew conflict increases exponentially. Anecdotal reports indicate extensive training requirements and scheduling limitations make it difficult to get crewmembers time to train as a team. Increasing crew size and new operating systems (associated with the Constellation project) will no doubt create additional difficulties in training crewmembers as a team.

Poor cohesion, poor composition, inadequate training, and difficulties adapting will have more pronounced consequences during long-term lunar and Mars missions, where there will be fewer resources for mitigating the effect of these factors on performance. Prolonged or pronounced exposure to stressors, such as interpersonal conflict, may produce strain among crewmembers; and strain is associated with negative physiological and mental health consequences. These health risks may become compounded by the fact that lunar and Mars missions introduce additional restrictions and stressors compared to Astronauts' mission experiences to date.

Currently, the Spaceflight Human System Standards (Standard 5.2.3) state training shall be provided on psychosocial phenomena experienced by crews, and training regarding crew integration and team dynamics may be included. The current standards, however, do not define such training or ensure it will be available to crews prior to long-duration missions. Given the noted relationship between team composition, team training, cohesion, psychosocial adaptation and performance, future spaceflight endeavors would benefit from specifying some standard of psychosocial training and support for all crews prior to flight.

VII. Gaps

BHP provides tools and technologies that support crew health to prevent or mitigate the risk of human performance errors due to poor cohesion and performance, selection/team composition, training and psychosocial adaptation (Team Risk). These efforts are operationally driven, consistent with human health and performance standards, and aligned with major Constellation milestones. In an effort to prioritize gaps and related activities and deliverables, BHP weighed each deliverable's operational relevance, role in risk reduction, and advancement of countermeasure development, in light of crew needs during Exploration Missions.

Veteran astronauts and ground personnel have expressed the need for training requirements to improve crew cohesion in order to reduce the likelihood of performance errors caused by inconsistent and suboptimal team dynamics. Reportedly, some missions may have been jeopardized and possibly terminated as a result of interpersonal frictions; therefore,

BHP's first priority within the Team Risk involves reducing the risk of team conflict and developing appropriate countermeasures. To this end, BHP is collaborating with CB/JSC Astronaut Office and flight surgeons to systematically collect information directly from the long-duration flyers. BHP is also evaluating conflict management and communication tools for use by crews during spaceflight. BHP will provide recommendations based on the outcome from these research tasks. Additionally, BHP is collaborating with the Human Behavior and Performance (HBP) International Working Group on the HBP Competency Model to ensure adequate team training of astronauts by NASA and International Space Agencies. The BHP gaps that address these issues are:

1. What is the experience of spaceflight crews regarding team cohesion, psychosocial adaptation, and training?
2. What are the most effective methods for maintaining crew cohesion and ground communication, so they can manage and resolve conflict in space?
3. What are the best methods for training crews to maintain cohesion and optimal performance during exploration missions?

Long-duration missions to remote environments will increase the astronaut's exposure to extreme isolation and confinement resulting in higher stress levels and an increased risk of crew morale deterioration. The methods used to deal with crew stress could be critical to the mission's success. Therefore, BHP's second priority within the Team Risk involves providing unobtrusive monitoring technologies for deteriorated crew cohesion. The BHP gap that addresses this issue is: What methods and technologies can be developed to monitor crew coping with the behavioral conditions of spaceflight?

Evidence supports the important role group cohesion plays in team performance; cohesive teams perform higher than less cohesive teams. Research demonstrates team selection factors influence team cohesion; thus, it is important to examine and implement practices to secure the strongest or most ideal team composition for Exploration Missions. Therefore, BHP's third priority within the Team Risk addresses recommendations for astronaut selection and team composition for Exploration Missions. The BHP gap that covers this issue is: What are the best (most effective and efficient) methods and tools for selecting and composing crews for optimal team performance during exploration missions?

VIII. Conclusion

The selection of crewmembers, team training, team building, and the psychosocial adaptation of the crew to the mission environment present several opportunities to encourage optimal performance, but more research must be done in order to inform operations of how to take advantage of these opportunities.

The BHP Element has identified gaps in knowledge and mitigation strategies related to these issues. In order to close these gaps, the BHP Element needs to pursue more rigorous longitudinal research designs and a multi-method research program. Spaceflight history and data is required to identify the performance objectives most likely to be influenced by psychosocial team factors, to assess which factors are most salient on the job, to develop relevant measures of cohesion and psychosocial adaptation, and to determine the baselines of individual and team performance. Lab-based and space analogue studies are needed to pilot countermeasures and monitoring technologies, and to help identify the safest and most efficient means of manipulating factors to optimize performance.

Finally, high-fidelity space analogues or current spaceflight studies are needed to test the utility of the tools and countermeasures designed to promote optimal performance and support the psychosocial health of astronauts on long-duration missions. The funding and support of this research is justified by the potential benefits of knowing how to promote optimal performance, because the surest way to reduce the risk of failure when we are unable to isolate and eliminate potential error sources is to achieve optimal performance.

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XI. List of Acronyms

ARI	Army Research Institute
BHP	Behavioral Health and Performance
CB	Flight Crew Operations Directorate- Astronaut Office
HBP	Human Behavior and Performance
ISS	International Space Station
JSC	Johnson Space Center
NASA	National Aeronautic and Space Administration
NOLS	National Outdoor Leadership School
PCI	Personality Characteristics Inventory
PRD	Program Requirements Document
SMM	Shared mental models

XII. Glossary

Cohesion	The strength or willingness of individuals to stick together and act as a unit.
Composition	The arrangement or mix of individuals into a group, team, or crew.
Crew	A group of astronauts assigned to a mission.
Group	A collection of individuals into one place at one period in time.
Interpersonal Interaction	A communication exchange (verbal and non-verbal) between two or more individuals.
Performance	The execution of an action.
Performance Error	An act that deviates from an established code or standard of performance.
Performance Standard	Specific requirements about how an action should be executed.
Personality	A person's unique set of behavioral or cognitive patterns (usually described using five "big five" broad factors: Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism)
Psychosocial Adaptation	An individual's social, mental, and emotional adjustment to the stressors inherent in a particular environment or state of existence; quality of life as determined by an individual's subjective perception of his/ her situation
Shared Mental Model	Shared beliefs among team members about how things work and what actions will result in various conditions; An organized set of expectations for performance and common understanding of the resources available among team members
Selection	The choice of one individual for a particular purpose or role
Strain	A state of injury induced by prolonged or pronounced exposure to tension or stress
Stress	Tension resulting from factors that alter a current or expected state of equilibrium
Stressor	A stimulus that causes stress
Team	A collection of individuals working cooperatively toward a common goal or common set of goals; the collection of individuals assigned to support and

	achieve a particular mission
Team Skills Training	Educating or teaching an individual about the skills and knowledge associated with effective team performance
Team Training	Educating or teaching skills to a team, as a whole (rather than educating individual team members separately)
Training	The act of educating or teaching skills or knowledge; The skills, knowledge, or experience obtain through instruction or education